QR-96-TR-9516-008

Virtual Reality Battle Management Tool for Command, Control, and Communications Networks

Situation Awareness Virtual Environment for Networks (SAVENet) Final Report

CDRL A001

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1. SCOPE

1.1 IDENTIFICATION

The Final Report describes the work performed by Quality Research under the Virtual Reality Battle Management Tool for Command, Control, and Communications Networks contract (Contract Number DAAL01-96-R-9516) with the Army Research Laboratory. The end product of this contractual effort is a software prototype to aid battlefield commanders in managing command and control networks. This prototype is known as the Situation Awareness Virtual Environment for Networks (SAVENet). The initial release of SAVENet is given the version number of SAVENet 1.0.

1.2 SYSTEM OVERVIEW

1.2.1 Background

SAVENet is being built as part of a feasibility study for a Phase I Small Business Innovative Research (SBIR) program. During Phase II of the SBIR program, requirements for the final SAVENet Tool will be developed and the prototype converted into the final product. The sponsor of and funding agency for SAVENet is the Army Research Laboratory (ARL). SAVENet was developed by Quality Research with support from GTE and the University of Alabama in Huntsville (UAH). The primary end users of SAVENet are ARL staff members who will use SAVENet as an interim demonstration product to illustrate the capabilities of the final SAVENet tool. These demonstrations will typically be held at military conferences and industrial trade shows. Secondary end users are Government and commercial organizations that will be provided a copy of the tool by ARL for evaluation.

SAVENet is a virtual reality demonstration tool to support real-time battle management of an interactive combat network extending over several echelons and across several types of nets. The tool uses a British Telecom approach to Command, Control, and Communication (C3) net visualization and provides valuable assistance to simulation managers and battlefield commanders in designing and optimizing complex data networks. SAVENet uses an open architecture, platform-independent, multiple participant approach.

1.2.2 History

SAVENet was built using a virtual reality software product called Prospect. Prospect was developed in 1995 and 1996 through a Co-operative Research and Development Agreement between Quality Research and UAH. SAVENet is capable of operating on a variety of workstations; e.g., Silicon Graphics under UNIX, Intergraph under Windows NT, IBM PC-compatible under Windows NT, IBM PC-compatible under Windows 95, Macintosh Power PC,

DEC Alpha under UNIX, thus providing a wide variety of cost and performance options to the end user.

2. DEVELOPMENT ACTIVITIES

2.1 DEVELOPMENT SCHEDULE

Figure 2.1-1 provides the overall schedule of development of SAVENet. All SAVENet activities have been completed within the SBIR funding provided by ARL, as illustrated by Figure 2.1-2.

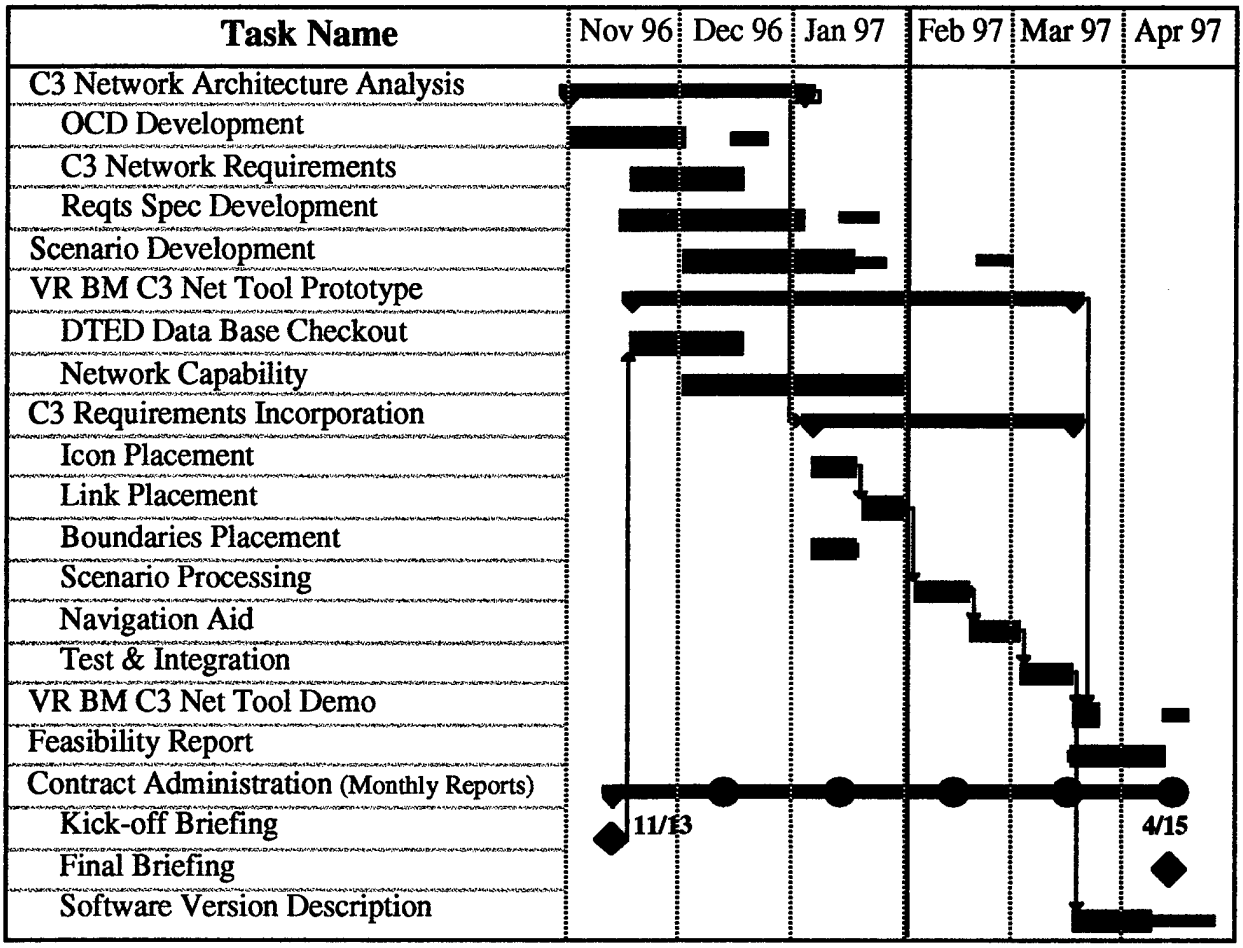

Figure 2.1-1 SAVENet Development Schedule

As part of the SAVENet development effort, Quality Research produced a Operational Concept Document (QR-96-TR-9516-001), a System Specification (QR-96-TR-9516-002), and a Software Version Description (QR-96-TR-9516-009). Progress toward the development of the SAVENet product was documented via a series of monthly reports.

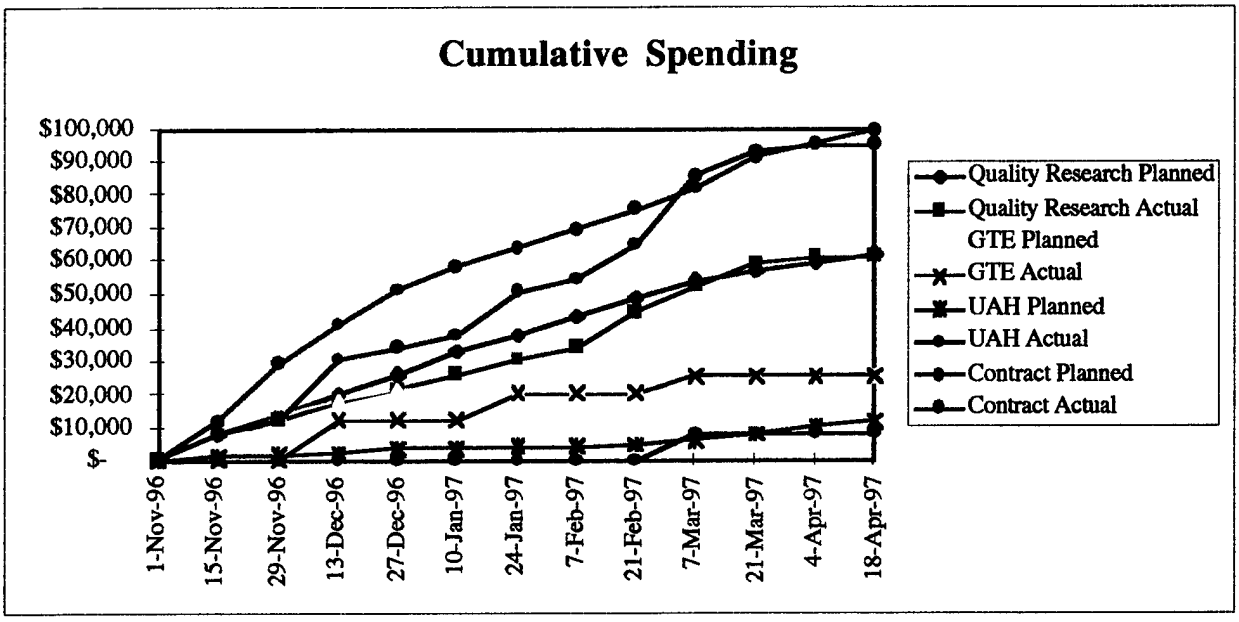

Figure 2.1-2 SAVENet Planned and Actual Expenditures

3. SAVENET DESCRIPTION

3.1 STATES AND MODES

SAVENet operates in only one state, the Execution State. System maintenance is performed by an expert developer.

3.2 SYSTEM CAPABILITIES

3.2.1 Terrain Database Display Capability

SAVENet provides the ability to display terrain data using the United States Geological Survey Digital Elevation Map (USGS DEM) terrain data from northern Kuwait.

3.2.2 Virtual Reality Visualization Capability

SAVENet provides the user the ability to maneuver through the terrain database as if the user were in a high performance jet. Maneuvering is controlled via a three button mouse. When the user reaches a point of interest, the user can "drill down" for a detailed look at his C3 assets.

3.2.3 C3 Assets Display Capability

SAVENet provides multiple views of the battle space to the user -- a Corps Level, a Network Level, and an Equipment Level. The Corps Level view is defined to be the view from 20,000 meters or above. The Network Level view is from 100 meters to 20,000 meters. The Equipment Level view will be below 100 meters. Examples of these views are provided in Figures 3.2-1, 3.2-2, and 3.2-6.

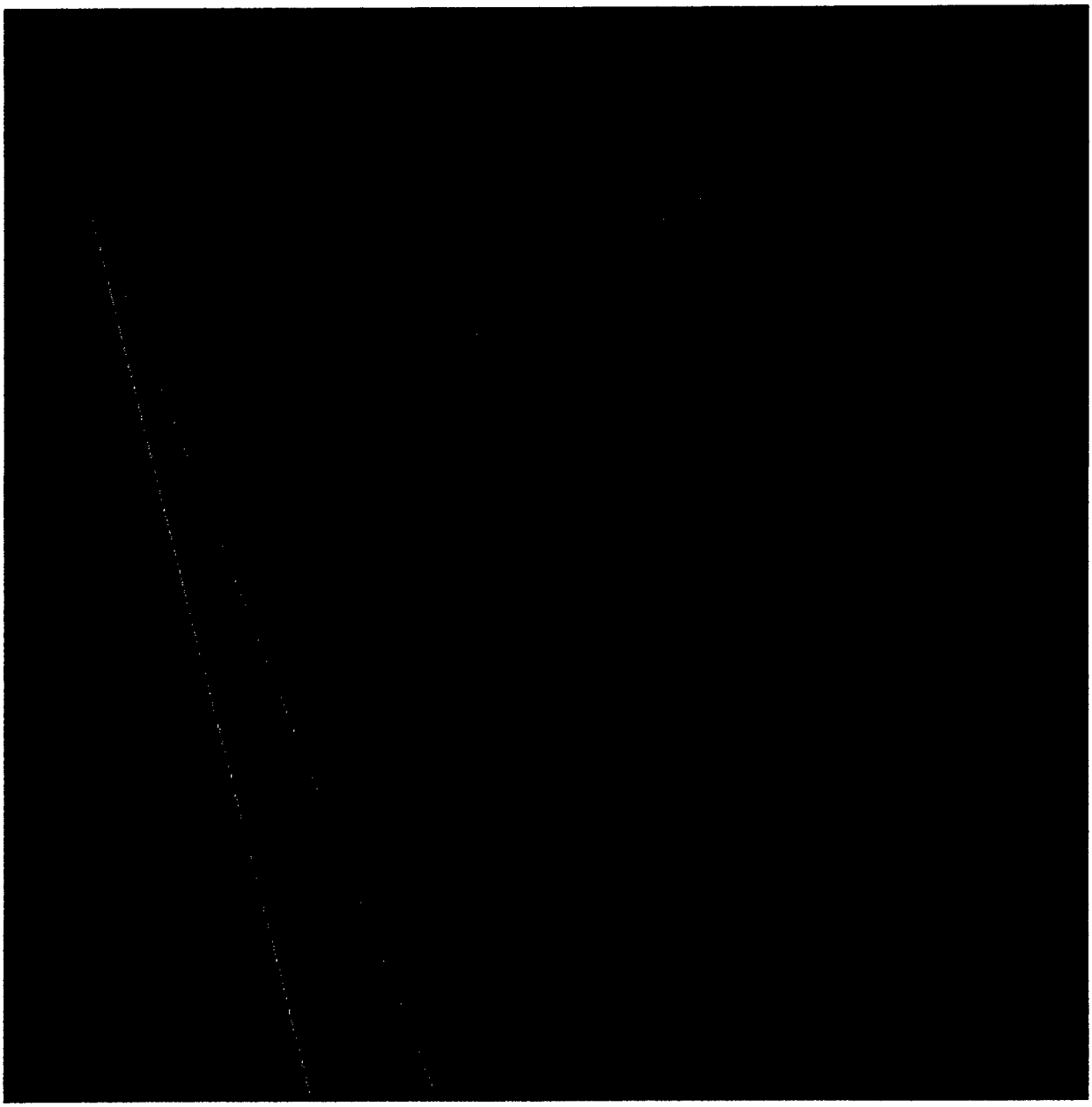

Figure 3.2-1 SAVENet Corps Level View of Battlefield

3.2.3.1 Corps Level Display Capability

Various graphical symbols are displayed on the Corps Level. Military unit symbols consist of several parts, as illustrated in Figure 3.2-3.

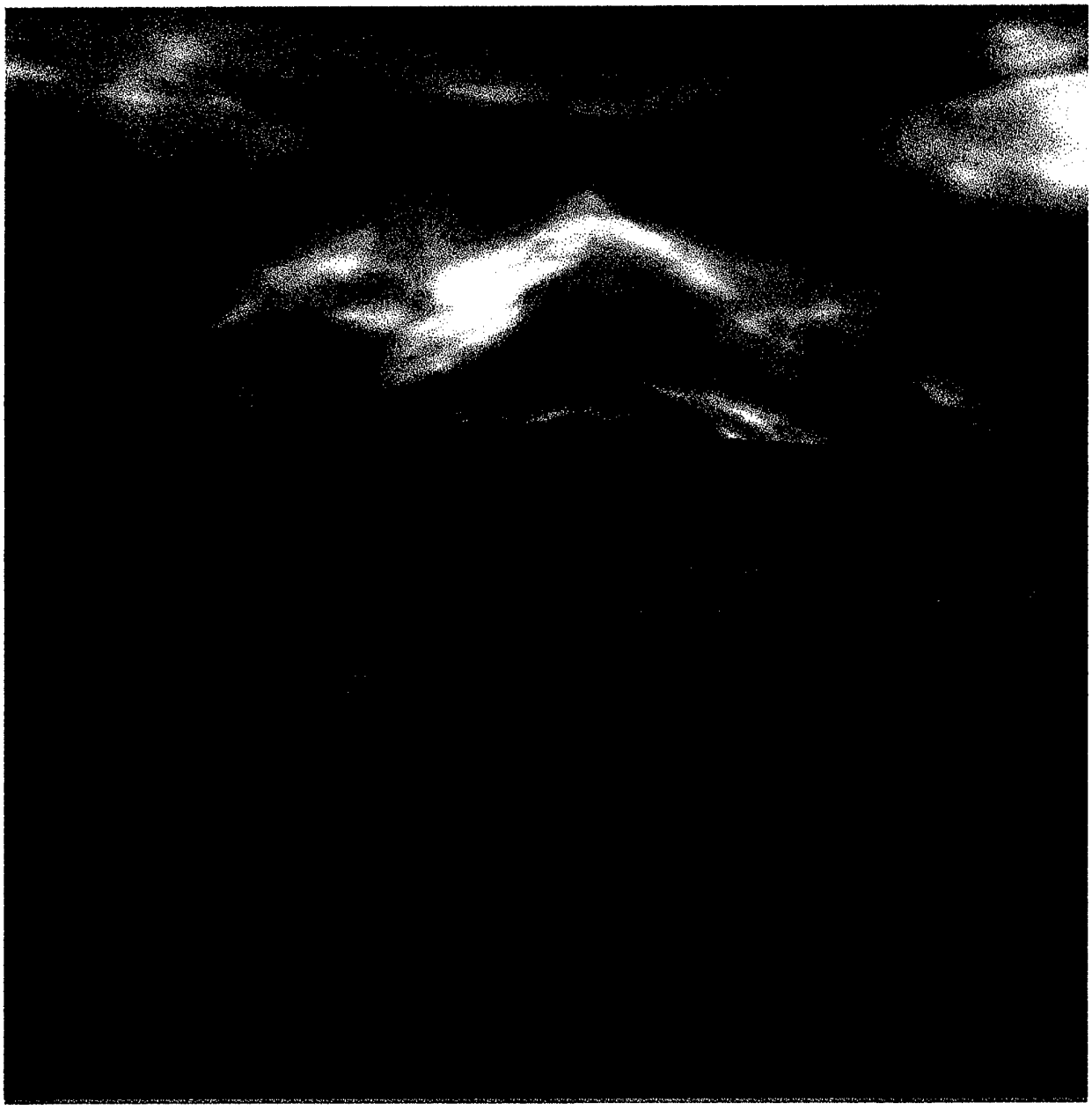

Figure 3.2-2 SAVENet Network Level View of Battlefield

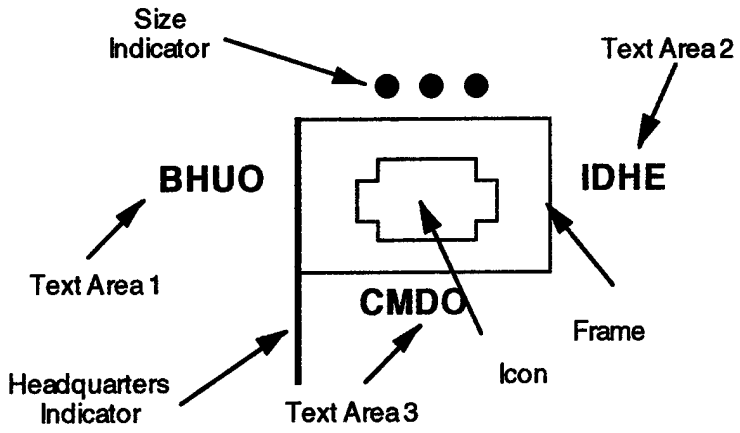

Figure 3.2-3 Military Unit Symbols Parts

When SAVENet is initiated, the user is brought to a position 8 kilometers directly south of Corps Headquarters, at an altitude of 100 kilometers, and looking due north. The Corps Level Display is displayed whenever the virtual user is above 20 kilometers altitude. The Corps Level Display covers six contiguous 100,000 meter squares. At the Corps Level, SAVENet displays the terrain database of the region with military unit symbol for the Corps Headquarters, lateral boundaries, front line of own troops (FLOT) boundaries, and movement arrows as defined by MIL-STD-2525 and FM 21-30. The Corps Level Display does not display military unit symbols below corps size units. Lateral boundaries, FLOT boundaries, movement arrows, and military unit icons are displayed as two dimensional graphics. Lateral boundaries are drawn as line segments. FLOT boundaries are drawn as a sequence of semicircles. Movement arrows are drawn as line segments.

3.2.3.2 Network Level Display Capability

The Network Level Display is displayed whenever the virtual user is below 20 kilometers altitude. The Network Level Display displays communication nodes and communication links. The Network Level Display shows a four part communication link status glyph on each communications link. The Network Level Display displays (going clockwise from the upper left quadrant) the bandwidth, percent usage, forward error correction (FEC) indicator, and bit error rate data. Bandwidth are displayed in the format of NNNNK with leading zeros suppressed. (For example, a bandwidth of 0064K would be displayed as 64K.) The percent usage are displayed in the format of NN.NN% with leading zeros not suppressed. (For example, a percent usage of .0425 would be displayed as 04.25%.) The forward error correction indicator are displayed as a Y if FEC is on and as an N if FEC is off. Bit error rate data are displayed in scientific notation in the format of N.NNE-N with less significant digits truncated. (For example, a bit error rate of .08047 would be displayed as 8.04E-2.) The four part communication link status glyph are the same color as the communication link it described.

SAVENet changes the color of the link and the communications status glyph according to the following Per Cent Used table (where the per cent used is truncated to the nearest whole per cent):

0%	-	white
1-50%	-	light green
51-60%	-	yellow
61-85%	-	gold
86-98%	-	orange
99%	-	red

3.2.4 Navigation Aid Capability

SAVENet provides the ability to assist the user in navigating through the battlefield. The Navigation Aid has three parts -- a General Coordinated View of the battlefield, a Navigation Console, and a Resources and Status Console. These three parts are illustrated in Figures 3.2-4, 3.2-5, and 3.2-6.

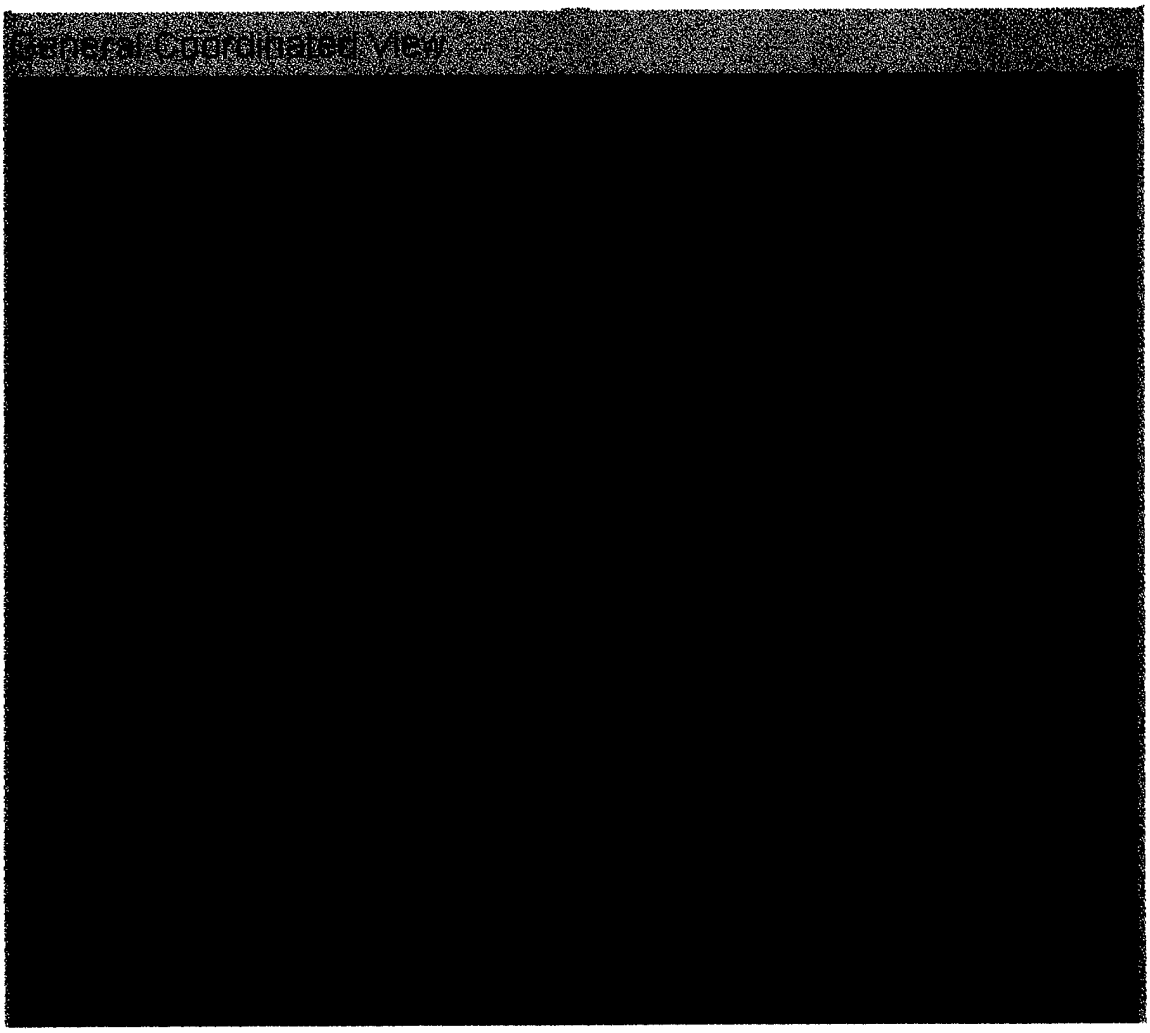

Figure 3.2-4 SAVENet Navigation Aid

Figure 3.2-5 SAVENet Navigation Console

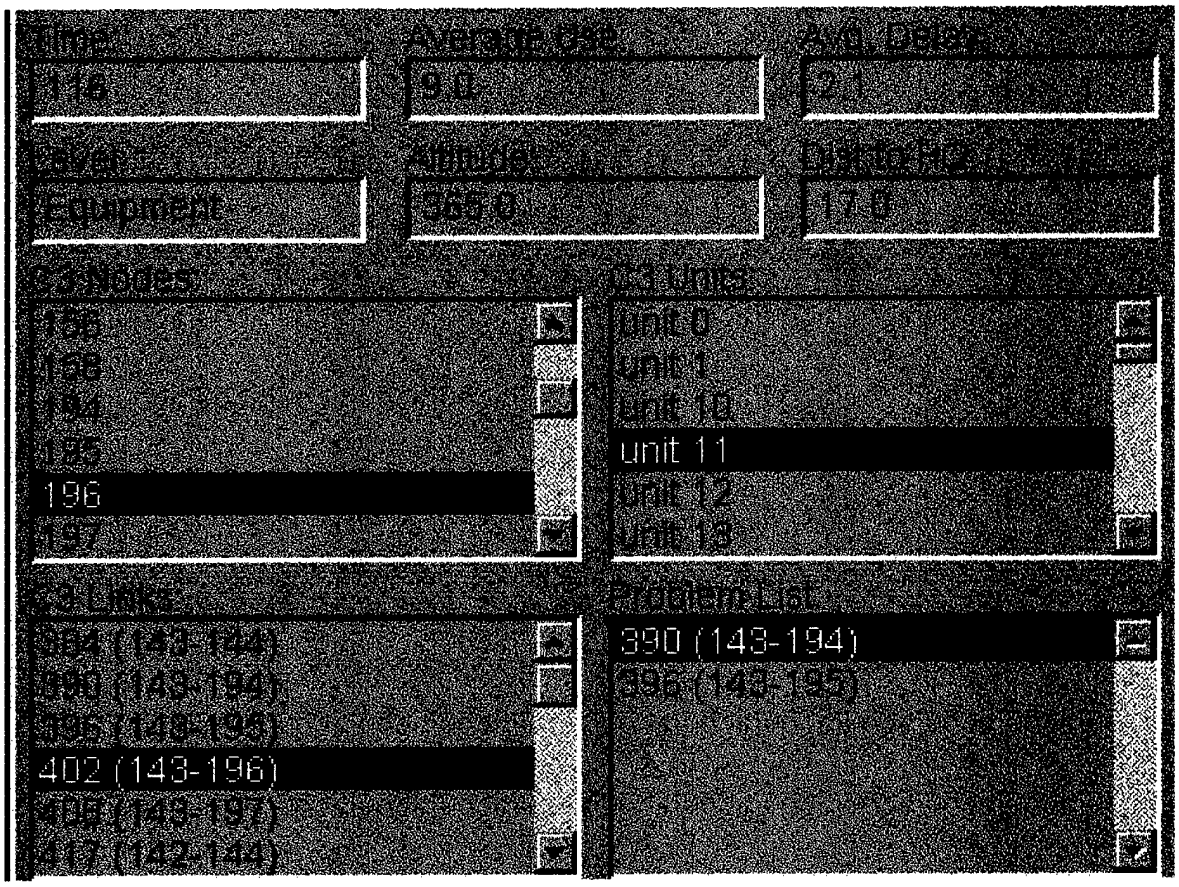

Figure 3.2-6 SAVENet Resources and Status Console

The General Coordinated View is placed in the lower right hand corner of the screen. The General Coordinated View provides a vertical downward view of the battlefield from a constant height of 25 kilometers. The General Coordinated View displays the view provided by the user's position and east-west/north-south orientation.

The Navigation Console provides a Stop Button and a Pause Button which are active if the data source is an internal simulation file, an Up 5Km Button to increase the altitude by 5 kilometers, a Down 5km Button to decrease the altitude by 5 kilometers, a Goto HQ Button to relocate the user to the nearest headquarters, a 10.0 meters per second velocity switch to aid in the speed at which the user navigates the terrain, and buttons to turn network link visibility on and off.

The Resource and Status Console provides a time indicator, an average use indicator, and average delay indicator, a description of the display level of the user, the altitude of the user, and the distance to nearest divisional or corps headquarters indicator. The Resource and Status Console

also provides a list of any C3 nodes, C3 units, C3 links, and any links that have exceeded an error threshold. The distance to corps headquarters indicator displays the distance in kilometers. The average use indicator are displayed in the format of NN% with leading zeros suppressed. The average delay indicator are displayed in the format of N.N with leading zeros not suppressed. The list of C3 problem list displays the link IDs for any links whose bit error rate exceeds 0.01. If the user clicks on an entry in the Problems List, SAVENet vectors the user to the location of the unit listed.

3.2.5 Equipment Level Display Capability

A feature to be investigated during Phase I of the SBIR effort is the final "drill down" to an Equipment Level display. Figure 3.2-7 is an illustration of how the drill down feature is implemented and is also an actual SAVENet screen capture. In Phase II, positions of C3 and other military assets would be determined from C3 network message traffic. The display would include a view of the actual equipment with equipment settings determined from the C3 network message traffic.

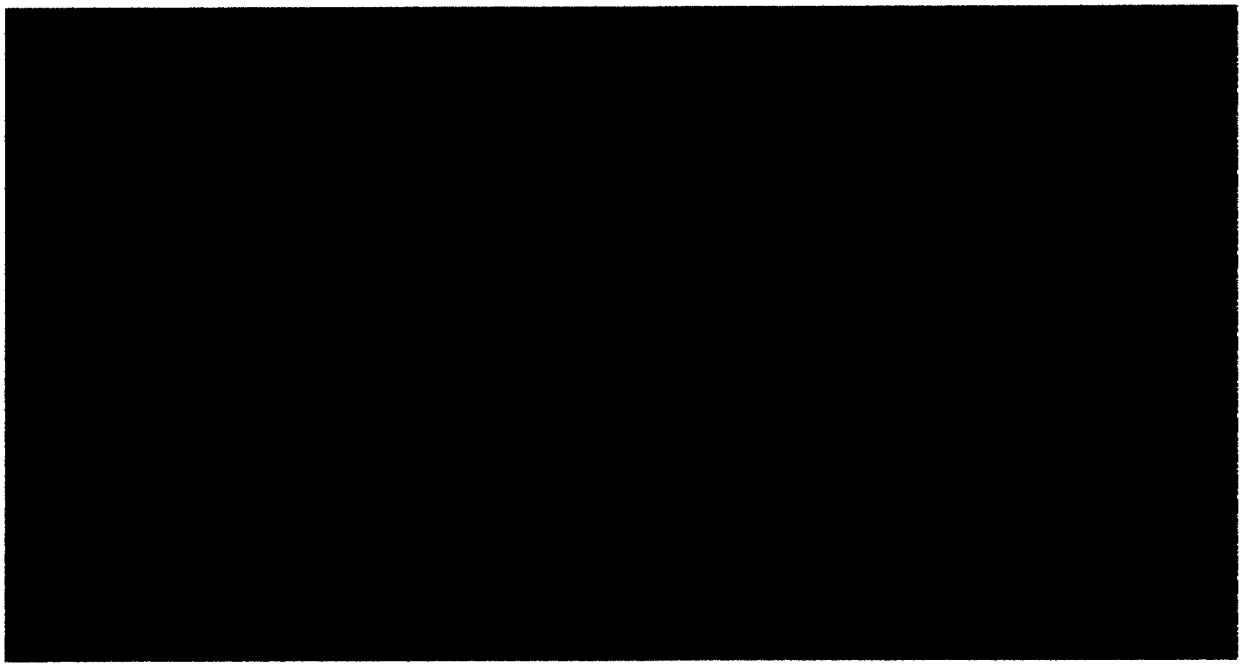

Figure 3.2-7 SAVENet Equipment Level Display

4. FEASIBILITY QUESTIONS

The following questions were raised in the original SBIR proposal and answered in Phase I to determine the feasibility of the proposed work:

- Will SAVENet provide the information needed by the battlefield commanders and their communications staffs to perform their duties?
- Will SAVENet provide the information needed by commercial communication resource providers to perform their duties?

- Does the SAVENet multiple participant capability provide a value added capability to battlefield commanders and their communications staffs?
- Does the architecture of the existing Quality Research/UAH RI Virtual Reality Tool Kit readily interface with both simulated C3 nets and real C3 nets?
- Can the tool be hosted on a low cost platform using a COTS, open architecture approach, or is a high end graphical platform required?
- Does a low cost platform implementation of the SAVENet provide adequate performance to support a commercial implementation?

4.1 BATTLEFIELD INFORMATION

Battlefield C3 message and display requirements were developed by battlefield communications experts from GTE and were implemented by Quality Research and UAH. Based on the battlefield C2 message and display requirements and the subsequent implementation, SAVENet will provide battlefield commanders and their communications staffs with the information needed to perform their duties. All C3 message and display requirements developed by GTE were based on current Army usage of the Multi-Switch Communication System and the ISYSCON network management system. SAVENet includes the ability to insert and remove nodes, to insert and remove links, and to change forward error correction settings. The display of C3 network data by SAVENet will provide the information needed by the battlefield commanders and their communications staffs to perform their duties.

4.2 COMMERCIAL COMMUNICATION RESOURCE PROVIDERS INFORMATION

In addition to being supported by GTE with the battlefield communications expertise, Quality Research was provided with access to the commercial communications experts from GTE. Message traffic and display requirements developed by GTE considered the information needed by commercial communication resource providers to perform their duties. Summary network traffic data provided by the ISYSCON network management system is compatible with and developed from network management required by and available to commercial communication network providers. The display of C3 network data by SAVENet will provide the information needed by commercial communication resource providers to perform their duties.

4.3 MULTIPLE PARTICIPANT CAPABILITY

SAVENet multiple participant capability provides battlefield commanders and their communications staffs with the ability to allow multiple users to simultaneously examine a battlefield network. Using this ability, a battlefield commander can assign multiple staff members to the analysis and management of a battlefield network. Problems that arise simultaneously at remote locations within the network can be analyzed jointly by multiple communication analysts in the same facility. Thus the SAVENet multiple participant capability provides a value added capability to battlefield commanders and their communications staffs.

4.4 SIMULATED C3 NETS AND REAL C3 NETS INTERFACE

The software architecture of the Quality Research/UAH Prospect tool interface to either simulated C3 nets and real C3 nets was designed with modularity and reuse in mind. For Phase I, external data is provided to SAVENet via data files. The design, however, considers these data files to be provided to the system through an abstract interface. That interface could be from a data file, a serial line, a TCP/IP socket, or a point-to-point protocol. Data is captured by the system by a "data grabber" that is interface unique. Whenever a new interface is required, a new "data grabber" would be required. Data is then passed to a "bookkeeper" that is responsible for keeping track of the status of the overall network. Typically, very few changes would be required to the "bookkeeper" to support a new interface. The rest of the SAVENet system should have no changes as the result of a new data interface. This is illustrated in Figure 4.4-1.

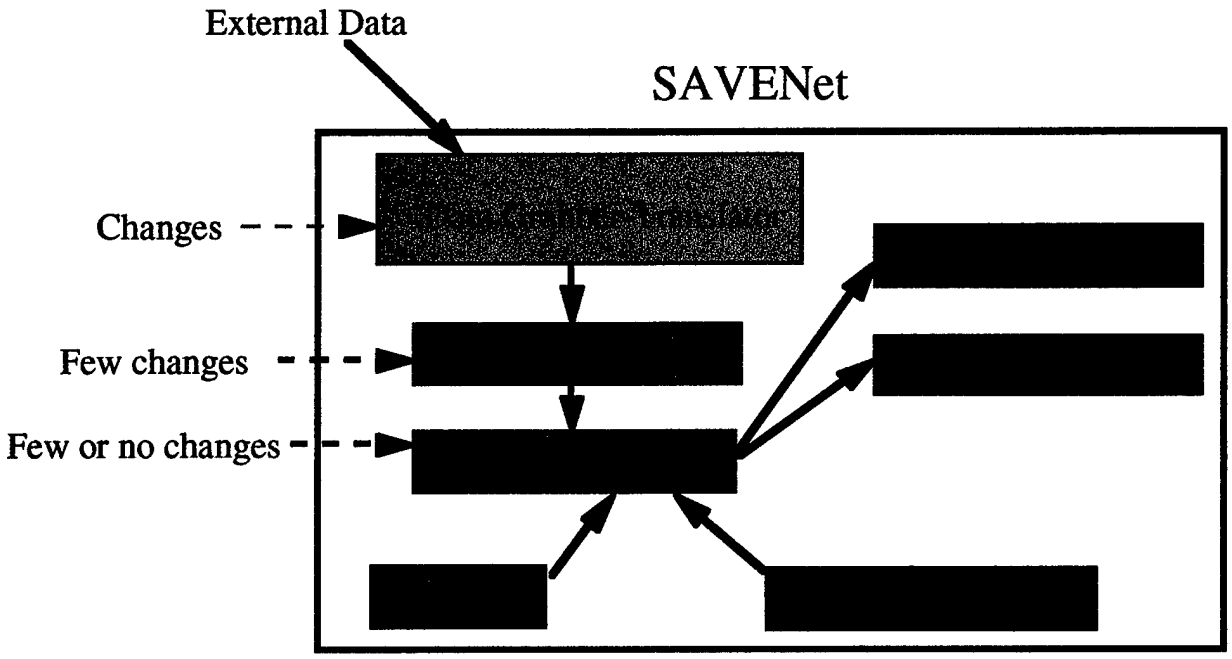

Figure 4.4-1 SAVENet External Interface Concept

4.5 LOW COST PLATFORM PERFORMANCE

Hardware costs for graphical workstations continue to drop and platform capabilities continue to grow. Over the last five years, prices for an adequate graphical workstation to perform the processing requirements of SAVENet have drop from six figures (>$100,000) to the low five figures (≈$15,000). Figure 4.5-1 is a summary of some material presented by Dave Randolph of Intergraph Corporation on April 10 at the Blue OCTOBER Workshop, with annotation to include data collected by Quality Research. The main development platform for the SAVENet effort had an original development cost of approximately $23K when purchased in the first quarter of the 1997

fiscal year. This system includes a graphics processing feature known as hardware texture mapping which enhances performance. Due to continuing cost and performance changes, the cost of the current equivalent replacement system is approximately $17K.

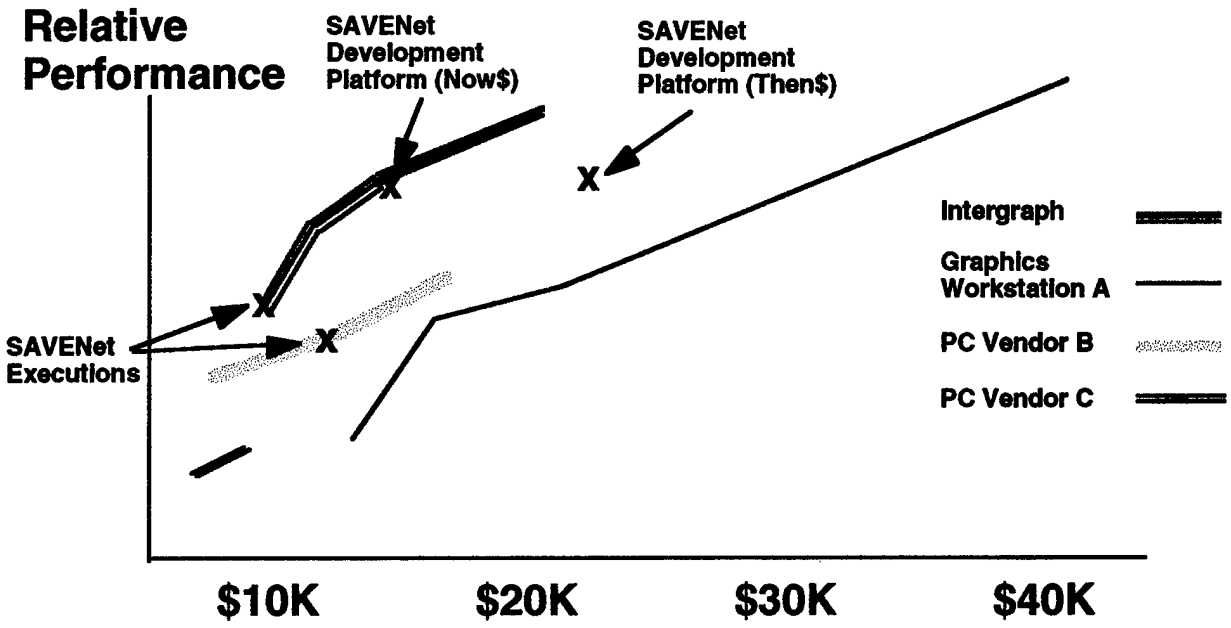

Figure 4.5-1 Workstation Performance

4.6 COMMERCIAL IMPLEMENTATION

Quality Research executed SAVENet on two other platforms -- a low end Intergraph system without texture mapping and a high end IBM PC-compatible with a specialized graphics card, also shown in Figure 4.5-1. Both systems had similar performance. The performance was on the low end of acceptable performance. Based on these two executions, Quality Research concluded that a low cost platform implementation of SAVENet will not provide adequate performance to support a commercial implementation, given the current performance characteristics of these machines. However, the continuing drop in hardware costs implies the cost/performance ratio will be favorable shortly.

5. SUMMARY

The SAVENet prototype was developed by Quality Research, UAH, and GTE based on an existing capability known as Prospect. The SAVENet prototype using a virtual reality concept developed by British Telecom to provide battlefield commanders and the communications staff with the ability to visualize and diagnose communications problems. SAVENet was developed using an open architecture, platform independent approach and is provided to the Army Research Laboratory with unlimited distribution rights.

6. NOTES

6.1 ACRONYMS AND ABBREVIATIONS

Acronyms/Abbreviations	Meaning
AL	Alabama
ARL	Army Research Laboratory
C3	Command, Control, Communications
CDRL	Contract Data Requirements List
DEM	Digital Elevation Map
FM	Field Manual
ISYSCOM	Integrated System Console
MA	Massachusetts
MD	Maryland
SBIR	Small Business Innovative Research
UAH	The University of Alabama in Huntsville
USGS	United States Geological Survey